Displacement of teeth without and with bonded fixed orthodontic retainers: 3D analysis using triangular target frames and optoelectronic motion tracking device

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Abstract: PURPOSE The objective of this study was to evaluate the anterior tooth movement without and with bonded fixed orthodontic retainers under incremental loading conditions. MATERIALS AND METHODS Six extracted mandibular anterior human teeth were embedded in acrylic resin in True Form I Arch type and 3D reconstruction of Digital Volume Tomography (DVT) images (0.4 mm voxels) were obtained. The anatomy of each tooth was segmented and digitally reconstructed using 3D visualization software for medical images (AMIRA, FEI SVG). The digital models of the teeth were repositioned to form an arch with constant curvature using a CAD software (Rhinoceros) and a base holder was designed fitting the shape of the roots. The clearance between the roots and their slot in the holder was kept constant at 0.3 mm to replicate the periodontal ligament thickness. The holder and the teeth were then manufactured by 3D printing (Objet Eden 260VS, Stratasys) using a resin material for dental applications (E = 2-3 GPa). The 3D-printed teeth models were then positioned in the holder and the root compartments were filled with silicone. The procedure was repeated to obtain three identical arch models. Each model was tested for tooth mobility by applying force increasing from 5 to 30 N with 5 N increments applied perpendicular on the lingual tooth surface on the incisal one third (crosshead speed: 0.1 mm/s). The teeth on each model were first tested without retainer (control) and subsequently with the bonded retainers (braided bonded retainer wire; Multi-strand 1 × 3 high performance wire, 0.022 × 0.016). Tooth displacement was measured in terms of complicance (F/Δ movement) (N/mm) using custom-built optoelectronic motion tracking device (OPTIS) (accuracy: 5 µm; sampling rate: 200 Hz). The position of the object was detected through three LEDs positioned in a fixed triangular shape on a metal support (Triangular Target Frame). The measurements were repeated for three times for each tooth. Data were analyzed using mixed model with nesting (alpha = 0.05). RESULTS The use of retainer showed a significant effect on tooth mobility (0.008 ± 0.004) compared to non-bonded teeth (control) (0.014 ± 0.009) ($p < 0.0001$). The amount of displacement on the tooth basis was also significantly different ($p = 0.0381$) being the most for tooth no. 42 (without: 0.024 ± 0.01; with: 0.012 ± 0.002) ($p = 0.0018$). No significant difference was observed between repeated measurements ($p = 0.097$) and the incremental magnitude of loading (5-30 N: 0.07 ± 0.01-0.09 ± 0.02) ($p > 0.05$). CONCLUSION Mandibular anterior teeth showed less tooth mobility when bonded with stainless steel wire as opposed to non-bonded teeth but the tooth mobility varied depending on the tooth type. Intermittent increase in loading from 5 to 30 N did not increase tooth displacement.

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Displacement of teeth without and with bonded fixed orthodontic retainers: 3D analysis using triangular target frames and optoelectronic motion tracking device

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Abstract

Purpose

The objective of this study was to evaluate the anterior tooth movement without and with bonded fixed orthodontic retainers under incremental loading conditions.

Materials and Methods

Six extracted mandibular anterior human teeth were embedded in acrylic resin in True Form I Arch type and 3D reconstruction of Digital Volume Tomography (DVT) images (0.4 mm^3 voxels) were obtained. The anatomy of each tooth was segmented and digitally reconstructed using 3D visualization software for medical images (AMIRA, FEI SVG). The digital models of the teeth were repositioned to form an arch with constant curvature using a CAD software (Rhinoceros) and a base holder was designed fitting the shape of the roots. The clearance between the roots and their slot in the holder was kept constant at 0.3 mm to replicate the periodontal ligament thickness. The holder and the teeth were then manufactured by 3D printing (Objet Eden 260VS, Stratasys) using a resin material for dental applications (E=2-3 GPa). The 3D-printed teeth models were then positioned in the holder and the root compartments were filled with silicone. The procedure was repeated to obtain three identical arch models. Each model was tested for tooth mobility by applying force increasing from 5 to 30 N with 5 N increments applied perpendicular on the lingual tooth surface on the incisal one third (crosshead speed: 0.1 mm/s). The teeth on each model were first tested without retainer (control) and subsequently with the bonded retainers (braided bonded retainer wire; Multi-strand 1x3 high performance wire, 0.022” x 0.016”). Tooth displacement was measured in terms of complicance (F/Δ movement) (N/mm) using custom-built optoelectronic motion tracking device (OPTIS) (accuracy: 5 μm; sampling rate: 200 Hz). The position of the object was detected through three LEDs positioned in a fixed triangular shape on a metal

support (Triangular Target Frame). The measurements were repeated for three times for each tooth. Data were analysed using mixed model with nesting (alpha=0.05).

Results

The use of retainer showed a significant effect on tooth mobility (0.008±0.004) compared to non-bonded teeth (control) (0.014±0.009) ($p<0.0001$). The amount of displacement on the tooth basis was also significantly different ($p=0.0381$) being the most for tooth no. 42 (without: 0.024±0.01; with: 0.012±0.002) ($p=0.0018$). No significant difference was observed between repeated measurements ($p=0.097$) and the incremental magnitude of loading (5-30 N: 0.07±0.01- 0.09±0.02) ($p>0.05$).

Conclusion

Mandibular anterior teeth showed less tooth mobility when bonded with stainless steel wire as opposed to non-bonded teeth but the tooth mobility varied depending on the tooth type. Intermittent increase in loading from 5 to 30 N did not increase tooth displacement.

Keywords: Adhesion; bonded retainers; dynamic stereometry; periodontal ligament; three-dimensional; tooth movement

1. Introduction

After an orthodontic treatment, the aligned teeth in their achieved positions need to be stabilized using bonded retainers (Little et al., 1998; Shah, 2003). In the absence of retention, 40 to 90% of relapse has been reported up to 10 to 20 years (Little et al., 1998; Al Yami et al., 1999; Kim et al. 1999). Failure of such bonded retainers is however a frequently observed clinical problem after the active treatment and when unnoticed they may lead to unwanted tooth movement (Radlanski et al., 2004). This is due to the fact that teeth have a tendency to return to their former position which is typically described as orthodontic relapse (Joondeph, 2011). Possible causes for such unwanted post-treatment tooth movements are multifactorial and have been attributed to the reorganization of the supporting tissues surrounding the teeth, neuromuscular imbalances, continued facial growth, aging and continuous unwanted oral habits (Reitan et al., 1960, 1967; Vaden et al. 1997; Blake et al. 1998; Rossouw, 1999; Joondeph, 2011; Heyman et al., 2012). Prevention of these unwanted tooth movements is a necessity in order to maintain the achieved orthodontic result (Dahl et al. 1991)

Bonded retainers usually made of single or multi-stranded stainless steel wires are considered as golden standard in orthodontics with the advantage of allowance for physiologic tooth movement compared to more stiff materials such as fiber reinforced composites (Bearn, 1995; Zachrison, 2015) Yet, a high incidence of failures, varying from 5.9 to 53% has been reported in previous studies, regardless of the variations in material types, configurations and application modes of bonded retainers (Segner and Heinici, 2000; Lie Sam Foek et al., 2008; Pandis et al., 2013) Nevertheless, former studies have shown that failure rates were often independent of gender, age and operator experience which leads to the assumption that the biological and physiological factors are more responsible causes for unwanted tooth movement and thereby debonding of the retainers (Lie Sam Foek et al., 2008; Maltha et al. 2017) In this context, periodontal ligaments (PDL) and gingival fibers composing the periodontium are stretched during tooth movement of any kind, which may cause strain between the bonded retainer and the tooth surface (Gerami et al. 2012; Franzen et al., 2013; Maltha et al., 2017). The role of PDL on relapse has been studied in animal experiments mainly on two teeth without considering the arch formation (Maltha et al., 2017). In fact, the force distribution could be anticipated to decraese when they are disseminated on multiple teeth in an arch where the retainers are bonded. To the best of our knowledge, no study has looked at the tooth displacement in a configuration of the frontal mandibular arch. Yet, it is not an easy task to study the amount of tooth displacement in a complete arch segment under administered magnitudes of forces. Establishment of a model for measurement of tooth mobility under different bonded materials would also allow making measurements for different adhesives and retainer materials.

The objectives of this study therefore were to investigate the anterior tooth movement without and with bonded fixed orthodontic retainers under incremental loading conditions. The hypotheses tested were that a) the use of bonded retainer would show less tooth mobility as opposed to non-bonded ones, b) the tooth mobility would increase with the increased magnitude of force and c) displacement amount would be similar regardless of the tooth type.

2. Material and methods

2.1 Model preparation

Six extracted mandibular anterior human teeth were embedded in acrylic resin (Technovit, Kulzer GmbH, Wehrheim, Germany), in True Form I Arch type (G&H Wires, Franklin, Indiana, USA) and 3D reconstruction of Digital Volume Tomography (DVT) images (Kavo 3D Exam1, Kavo GmbH, Leutkirsch, Germany) (0.4 mm^3 voxels) were obtained. All teeth used in the present study were extracted for reasons unrelated to this project. Written informed consent for research purpose of the extracted teeth was obtained by the donor prior to extraction according to the directives set by the National Federal Council. Ethical guidelines were strictly followed and irreversible anonymization was performed in accordance with State and Federal Law (World Medical Association, Declaration of Helsinki, 2013; Human Research Act, 2015). The anatomy of each tooth was segmented and digitally reconstructed using 3D visualization software for medical images (AMIRA, FEI SVG, Thermo Fisher Scientific, Hillsboro, Oregon, USA). The digital models of the teeth were repositioned to form an arch with constant curvature using CAD software (Rhinoceros, Mc Neel Euope, Barcelona, Spain) and a base holder was designed fitting the shape of the roots. The clearance between the roots and their slot in the holder was kept constant at 0.3 mm to replicate the periodontal ligament thickness (Provatidis, 2000). The holder and the teeth were then manufactured by 3D printing (Obect Eden 260VS, Stratasys, Commerce Way Eden Prairie, Minesota, USA) using a resin material for dental applications (Clear Biocompatible, MED 610, Stratasys, Commerce Way Eden Prairie) (E= 2-3 GPa). The 3D-printed teeth models were then positioned in the holder and the root compartments were filled with silicone (President, Coltene, Altstätten, Switzerland). The procedure was repeated to obtain three identical arch models.

2.2 Experimental procedures

Tooth mobility was tested by applying force increasing from 5 to 30 N with 5 N increments applied perpendicular on the lingual tooth surface on the incisal one-third at a crosshead speed of 0.1 mm/s. Each model was mounted on a custom-made loading device (RPETS, University of Zurich) allowing precise and repeatable positioning of the arch. The device was composed of two main parts: a metal support where the arch could be aligned with the teeth to be tested and motor controlled loading mechanism, pressing a conic shaped tip (single point force application) on the selected tooth with a prescribed force, measured by means of a force sensor (ME Messsysteme GmbH, Henningsdorf, Germany).

The teeth on each model were first tested without retainer that acted as the control group and subsequently with the bonded retainers (braided bonded retainer wire; Multi-strand 1x3 high performance wire, 0.022” x 0.016”, PG Supply Inc., Avon, Connecticut, USA). On the lingual surfaces of each tooth an adhesive resin was applied (Heliobond, Ivoclar Vivadent, Ivoclar Vivadent, Schaan, Lichtenstein) and photo-polymerized for 20 s (Bluephase, Ivoclar Vivadent). The lingual retainer was individually bent on all teeth and made sure to have a passive fit. The retainers were bonded on all teeth using resin composite (Tetric Evo Ceram, Ivoclar Vivadent) and photo polymerized for 20 s on each tooth (Figs. 1a-d).

Tooth displacement was measured using custom-built optoelectronic motion tracking device (OPTIS, University of Zurich, Switzerland) based on 3 non-collinear Charge-coupled device (CCD) cameras (Spectral Instruments, Tuscan, AZ, USA) recording the movements of Light Emitting Diodes (LEDs) with an accuracy of 5 μm and a sampling rate of 200 Hz. In order to define the position of the object to be detected, three LEDs are positioned in a fixed triangular shape on a metal support called Triangular Target Frame (TTF). One TTF was glued to each tooth and the other to the arch holder through which the relative movement of the tested tooth was determined. Digital models of the teeth were animated with the tracked movements by means of a custom-made software application (Figs. 2a-c).

The mid-incisal point (IP) of each tooth was marked and its trajectory was determined. The vector between two subsequent recorded positions of IP was computed. The relationship between the force and displacement for each tooth was determined by calculating the linear regression line between the values of the displacement vector obtained for each tooth at each adminstered force. The parameter “compliance” was observed as a measure of the response of the arch to the pressure in terms of elasticity, being the inverse of the elastic modulus (K) according to the following formulas:

$$K= F/\Delta M \quad (1)$$

where K was the elasticity modulus (GPa), F, the applied force (N), ΔM, change in movement (mm)

$$C=1/K \quad (2)$$

where C was the Compliance and K the elasticity modulus.

The measurements were repeated for three times for each tooth on each model yielding to 54 measurements.

2.3 Statistical analysis

Data were analyzed using a statistical software package (IBM SPSS Software V.23, Chicago, IL, USA). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test normal distribution of the data. Values of mean, standard deviation, maximum and minimum were calculated for all teeth in an arch in the two observed conditions (without and with the retainer) and for each tooth. In order to determine the dependency of tooth mobility as a function of 1) the use of a retainer, 2) the tooth position and 3) the repetition, a mixed effects statistical model with nesting was employed. “Arch” and “individual tooth” were considered as random factors and “individual tooth” was nested in “arch”. The “retainer”, “tooth position” and “repetition” were reflected as fixed factors. Furthermore, the logarithm of the slopes was taken in the mixed effects model in order not to violate modelling assumptions. P values less than 0.01 were considered to be statistically significant in all tests.

3. Results

Descriptive statistics results of the compliance derived from the control condition and with the retainer are presented in Table 1. Overall, the mean value of the compliance was smaller with the retainer than in the control condition.

The use of retainer showed a significant effect on tooth displacement (0.008±0.004) compared to non-bonded teeth (control) (0.014±0.009) ($p<0.0001$).

The amount of displacement on the tooth basis was also significantly different ($p=0.0381$) being the most for tooth no. 42 (without: 0.024±0.01; with: 0.012±0.002) ($p=0.0018$) (Table 2).

No significant difference was observed between repeated measurements ($p=0.097$) and the inceremental magnitude of loading (5-30 N: 0.07±0.01- 0.09±0.02) ($p>0.05$) (Figs. 3a-b).

4. Discussion

This study was undertaken in order to investigate the anterior tooth movement without and with bonded fixed stainless steel orthodontic retainers under loading conditions. Based on the results of this study, since the presence of retainer significantly decreased the tooth mobility, the first hypothesis could be accepted. However, the increased magnitude of force did not significantly effect the tooth displacement. Thus, the second hypothesis could be rejected. Displacement amount was similar in all teeth except for one, namely tooth number 42 and therefore, the third hypothesis could only be partially accepted.

A number of factors alone or simultaneously cause the failures of bonded retainers in orthodontics. Since the location, gender, composite type, humidity control, operator factor could not be disclosed in previously studies (Lie Sam Foek et al., 2008; Segner and Heinrici, 2000), tooth mobility was of focus in this study. In an attempt to make a close approximation to the clinical situation, an ideal mandibular arch model was chosen and the extracted human teeth from the same patient were positioned accordingly. The association between the debonding of retainers and tooth mobility was assessed previously on simplified models where the retainers were adhered to only two teeth set up (Lie Sam Foek et al., 2009; Paolone et al., 2015). However, the contradictory clinical findings and the ones obtained from such simplified models, encouraged us to use of a full segment when studying tooth displacement under loading and stability of bonded retainers. Furthermore, in an arch model, 'free wire' which should be ideally 2.5 mm in between the buds of resin composite adhered on the tooth surface allows for more flexibility of the wire compared to simplified models (Milheiro et al., 2015).

The methodology used in this study proved to be reproducible. Since the models with the teeth were replicas of the extracted human anterior teeth, the employed method could be used to study tooth displacement using other bonded retainer types. In this study, tooth displacement was measured under compression where the forces were increased by 5 N up to 30 N. Three dimensional tooth displacement was linearly correlated with the applied force. One can argue that 30 N is considerably less compared to normal masticatory forces. However, the linear increase exceeding 30 N was not significant in this study and therefore the threshold value of 30 N was considered as the highest magnitude of force. Nevertheless, in this study in none of the cases, debonding or other types of retainer failures were experienced. In both model scenarios without and with bonded retainers, the maximum compliance did not exceed 0.038 witout and 0.016 with retainer indicating that this amount of mobility does not yield to debonding, providing that some degree of tooth movement could also be dictated by the flexibility of the wire tested.

Typically, teeth are surrounded by the PDL which is a thin membrane consisting of collagen fibers. This ligament provides the attachment of the tooth to the surrounding alveolar bone, and under normal circumstances there is no direct contact between the root and the bone. Forces applied to the crown of the tooth are transmitted to the alveolar bone through this layer, stretching, and compressing the ligament (Van Schepdael et al., 2012). Different cell types, like fibroblasts, osteocytes and osteoblasts, respond to the changes in mechanical environment. This biological environment has been tried to be simulated using different materials in the dental literature. Some authors preferred to simulate the PDL with polyether (Behr et al., 1999; Rosentritt et al., 2006; Xie et al., 2007; Kolbeck et al., 2008; Minami et al., 2009), others gum resin (Kern et al., 1994; Chitmongkolsuk et al., 2002; Attia et al., 2006; Att et al., 2007), latex (Kohorst et al., 2007), wax (Pfeiffer and Grube, 2003), polysulfide (Grajower et al., 1981) or silicone (Wolfart et al., 2007). Provatidis (2000) followed the work of Haack and Haft (1972) in representing the root of a maxillary central incisor as a paraboloid, surrounded by the ligament. In the analyzed in vitro studies, dipping the roots in these materials simulated the presence of PDL. This simplistic approach considered neither the elastic modulus nor the thickness of the used PDL materials. Furthermore, since lateral displacement forces are dominated with the thickness of the PDL material, it can be expected that the forces would be unfavourable when PDL is thicker. In this study, although the tooth morphology varied in the studied sample, in an attempt to standardize the PDL thickness the clearance between the root surfaces and the model was maintained at 0.25 mm. A thickness of 0.229 mm was found to be common on maxillary incisors

(Provatidis, 2000). Also, the measurements were made consecutively in order to avoid the stiffness of the silicone material over time. Yet, due to the lack of neuromuscular forces silicone PDL could still be considered as a simplistic approach and therefore can only provide prediction of tooth displacement in relation to the used retainer or adhesive materials and the administered force applied. It has to be however noted that the mobility of the teeth as a segment alters after retainer placement following orthodontic treatment in that the tooth mobility decreases over time (Konermann et al., 2017). In fact, the first set of experiments without retainers did involve tooth mobility. Subsequently, the retainers were bonded on these mobilized teeth in an attempt to simulate the clinical mobility to some extent. Dental movements in the mouth due to lips and tongue, periodontal ligament, oral functions could not be replicated completely. Thus, the in vitro nature of such studies is certainly a setback but still provides a better understanding of the behaviour of the unit/segment effect with or without a retainer. In a set of previous studies, in order to study the performance of other retainer materials, models were created without simulation of the ligament and the arch form. These models could not identify the difference between the materials in terms of adhesion (Lie Sam Foek et al., 2009) or mechanical performance (Lie Sam Foek et al., 2013).

Although initially no significant difference was expected on the tooth type basis, interestingly, tooth number 42 showed the highest mean values for compliance. One possible explanation could be the root morphology of this very tooth which possibly differed from those of others. Since the clearance values was standard, the lack of significant difference in terms of compliance could be not be considered surprising. However, the significantly higher variation of compliance observed with tooth number 42 raises the question whether root morphology plays a role in the torsional component of the applied compressive load.

Measurement of tooth movement is a complex procedure and includes translational and rotational components of motion. In this study, only translations were quantified and they were linearly related to the force applied with compression steps of 5 N. It could be estimated that not only the compression but also torsional forces could be responsible for debonding of retainers. Furthermore, force in this study was applied at a constant speed and in clinical situations variable speeds of force may occur during function which may cause debonding of the retainers. As stated in literature, unexpected posttreatment changes in 3-5% of all patients occur, usually with differences in torque between two adjacent incisors or an altered inclination of the canine (Sifakakis et al. 2015). Allthough the exact reason for these unwanted changes is unknown, it is proposed that there must be an active component of the wire due to either an elastic deflection caused by the clinician or a mechanical deformation from masticatory forces which in turn may cause these movements. Due to these unexplained, yet clinically seen alterations, retainer wires with higher bending and torsional stiffness, may be more suitable for this clinical application (Sifakakis et al., 2015, Arnold et al., 2016). Similarly, the resin composite used in this study was a highly nano-filled flowable resin. Other composite materials could be tested in conjuction with other wires in this model along with fatigue conditions where shear, torsional forces and dynamic loading are simulated to introduce residual stresses between tooth-composite-retainer interfaces (Sifakakis et al., 2015).

Nevertheless, the analysis of tooth displacement could be instrumental for finite elements analysis of the stresses at the roots of the teeth with different types of lingual retainers or adhesives used. The tooth mobility obtained using stainless steel wires should be compared with those of fiber reinforced retainers where contradictory clinical results are presented some of which attributes the failures to the lack of mobility due to the stiffness of the material. The utilized method with its favourable reproducibility in this study could be instrumental for measurement of tooth displacement with fiber reinforced composite retainer types.

5. Conclusions

From this study, the following could be concluded:

1. Mandibular anterior teeth showed less tooth displacement when bonded with stainless steel wire compared to the non-bonded control group.
2. Tooth displacement varied on the mandibular arch depending on the tooth type being the highest for tooth number 42 in both bonded and non-bonded models.
3. Increase in the magnitude of force on the inciso-lingual direction on the teeth, intermittent from 5 to 30 N did not result in increased tooth displacement and the simulated model showed reliable reproducibility.

Clinical Relevance

Bonded stainless steel lingual retainers in the studied arch model resulted in less tooth movement compared to non-bonded ones not exceeding the mean value of 0.008. Intermitttent increase of loading from 5 to 30 N did not cause debonding of the retainer with the tested materials.

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Conflict of interest

The authors did not have any commercial interest in any of the materials used in this study.

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Figs. 1a-d Workflow of the model preparation. **a)** The anatomy of six anterior teeth (canine to canine) was acquired with DVT and digitally reconstructed; **b)** digital models of the teeth were repositioned to form a standard arch form, **c)** base holder was designed fitting the shape of the roots; **d)** holder and the teeth were manufactured using 3D printing and positioned in the holder where the root compartments were filled with silicon.

Figs. 2a-c. a) Custom-made device for force application on the lingual surfaces of the teeth on the mandibular arch composed of a metal support in which the arch is aligned with the tooth to be tested and electronically controlled loading mechanism, **b)** the arch model in its base holding the Triangular Target Frame (TTF) with light emitting diode (LED)s used during the kinematic recording and the conic shaped tip applying force on the selected tooth with the administered force, **c)** 3 non-collinear charge-coupled device (CCD) cameras used recording the movements of LEDs with an accuracy of 5 μm and a sampling rate of 200 Hz.

Figs. 3a-b. Displacement (mm) of teeth **a)** regardless of the tooth type in all mandibular arches tested, **b)** on the basis of tooth type as a function of incremental force application from 5 to 30 N.

Table 1. Descriptive statistics of the compliance results regardless of the tooth type and force in all tested mandibular arch models.

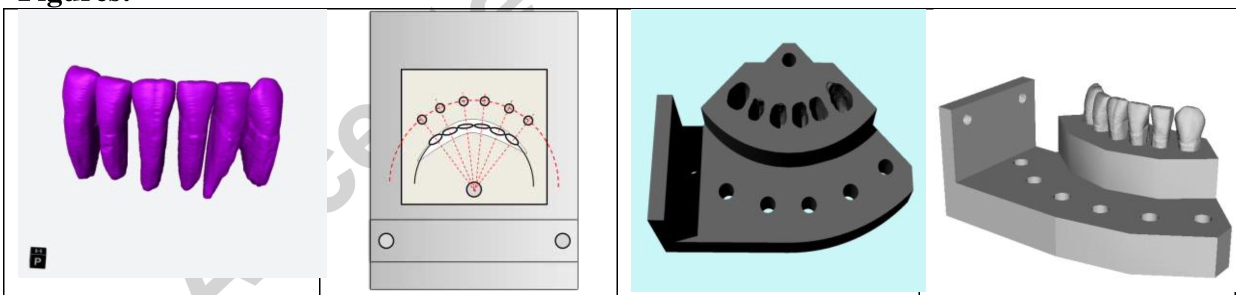
	Without Bonded Retainer (Control)	With Bonded Retainer
Mean	0.014	0.008
Median	0.013	0.008
Std. Deviation	0.009	0.004
Minimum	-0.001	-0.015

Maximum	0.038	0.016
CI Lower Bound	0.011	0.007
CI Upper Bound	0.016	0.009
Std. Error	0.001	0.001

Table 2. Descriptive statistics of the compliance results depending on tooth position for control and bonded retainer models.

	Without Bonded Retainer (Control)						**With Bonded Retainer**					
	t33	**t32**	**t31**	**t41**	**t42**	**t43**	**t33**	**t32**	**t31**	**t41**	**t42**	**t43**
Mean	0.015	0.012	0.010	0.013	0.024	0.008	0.009	0.008	0.007	0.009	0.012	0.002
Median	0.014	0.014	0.010	0.014	0.027	0.006	0.009	0.008	0.006	0.009	0.011	0.005
Std. Deviation	0.010	0.004	0.003	0.004	0.010	0.008	0.003	0.001	0.002	0.002	0.002	0.007
Minimum	0.004	0.007	0.006	0.007	0.012	-0.001	0.005	0.006	0.003	0.006	0.009	-0.015
Maximum	0.029	0.016	0.016	0.018	0.038	0.019	0.015	0.010	0.009	0.011	0.016	0.008
CI Lower Bound	0.007	0.009	0.008	0.010	0.017	0.001	0.007	0.007	0.005	0.007	0.010	0.010
CI Upper Bound	0.023	0.015	0.012	0.016	0.032	0.014	0.012	0.009	0.008	0.010	0.013	0.013
Std. Error	0.003	0.001	0.001	0.001	0.003	0.003	0.001	0.000	0.001	0.001	0.001	0.001

Figures:



a) b) c) d)

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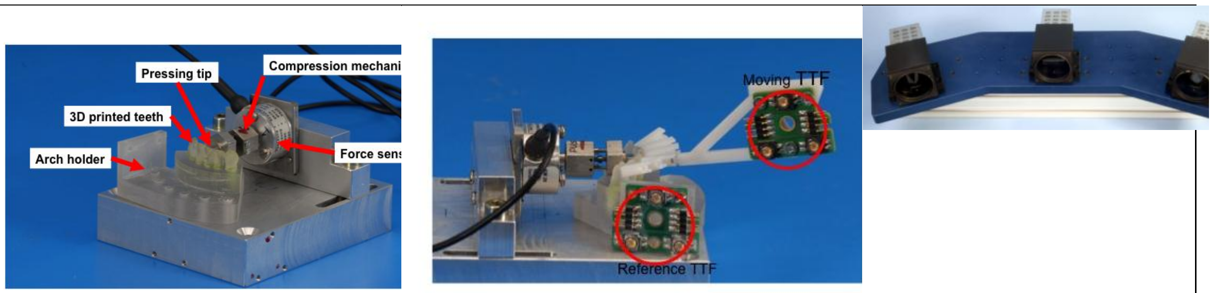

a) b) c)

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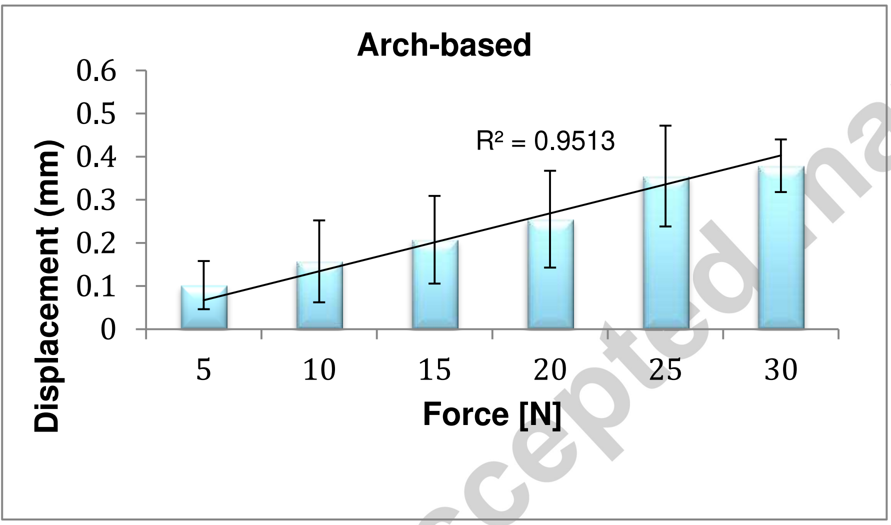
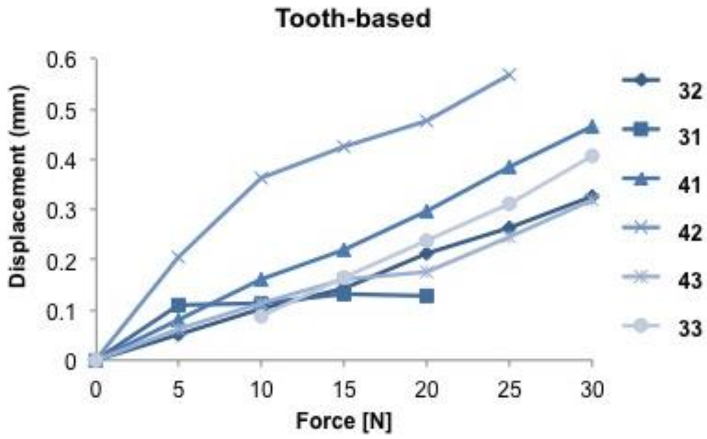


a)



b)

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